Satellite Communications

Roger Flaherty
GSFC Code 450
May, 2002

Satellite Communications

Agenda

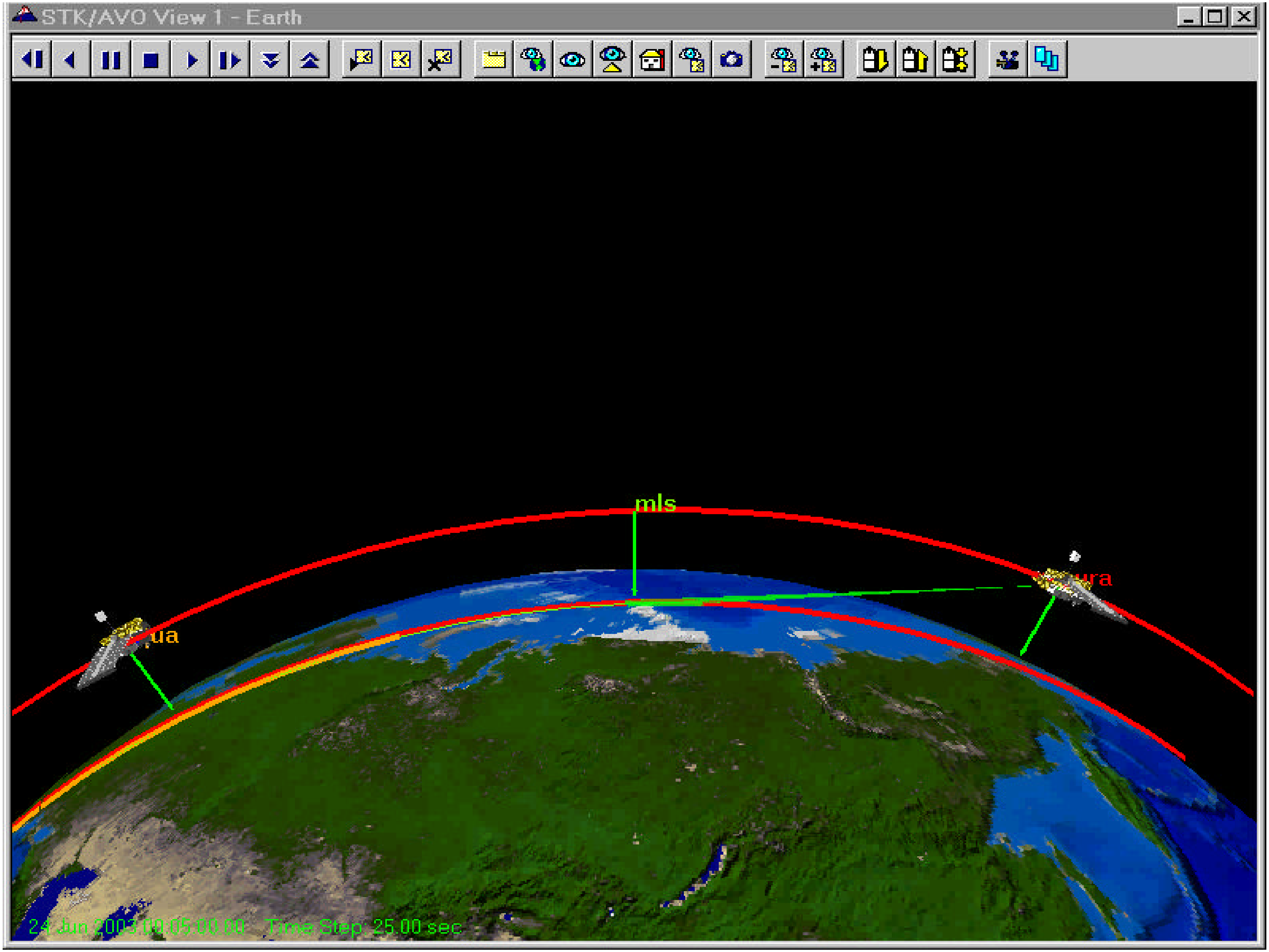
- Introduction
- Satellite Communication Options
- Evolution of Satellite Communications
- The Future
- Applications and Products of Satellite Communications

Introduction

Satellite Communications

Mission Design

- Mission Objectives
  - Earth Observing, Astronomy, Communications
- Spacecraft Design
  - Power requirements, Bus size, Mission duration
- Flight Dynamics
  - Type of Orbit
    - » Polar
    - » Equatorial
    - » Geosynchronous
- Mission Operations
  - Tracking, Telemetry, Command


STK/AVO View 1 - Earth
mls
ua
ra
24 Jun 2003 00:05:00.00   Time Step: 25.00 sec

Satellite Communications

Commercial vs. Government Missions

- Commercial Communications Missions
  - Commercial Communication Missions are designed as revenue generating business enterprises
  - Direct Broadcast such as Direct TV or XM (Direct TV-4)
  - Telephone, Paging (IRIDIUM)

- Government Communication Missions
  - Government Communication Missions generally support higher data rates generated by remote sensing, International Space Station (ISS) and Shuttle missions
  - Government Missions also provide a test bed for proof of concept experimentation for new technologies such as Internet Protocol (IP) in space
    - » Tracking and Data Relay Satellite (TDRS)
    - » Defense Satellite Communication System (DSCS)

Satellite Communications

Satellite Design

Satellite design is based largely on the mission objectives

Tracking and Data Relay Satellite
(High Data Rate Communications Relay)

Hubble Space Telescope
(Astronomic Observatory)

Eutelsat (Commercial Communication)

EOS- TERRA (Earth Observing)

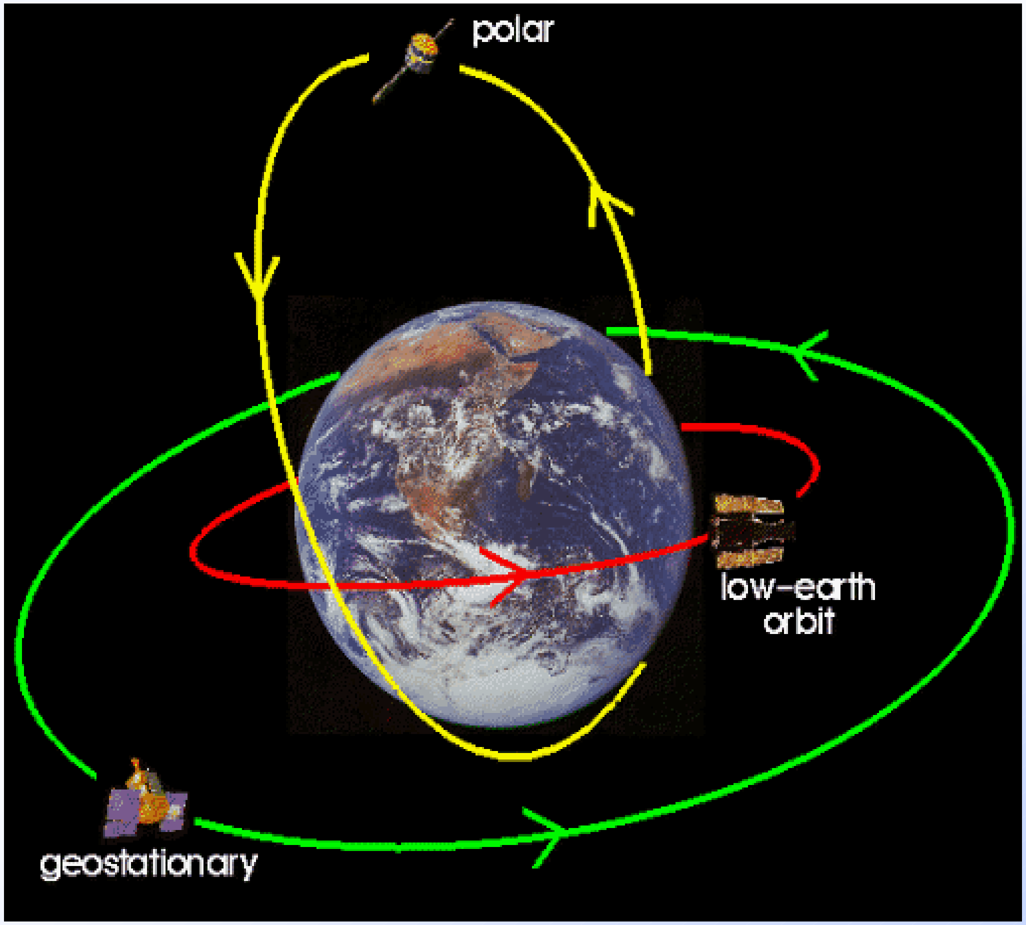
Satellite Communications

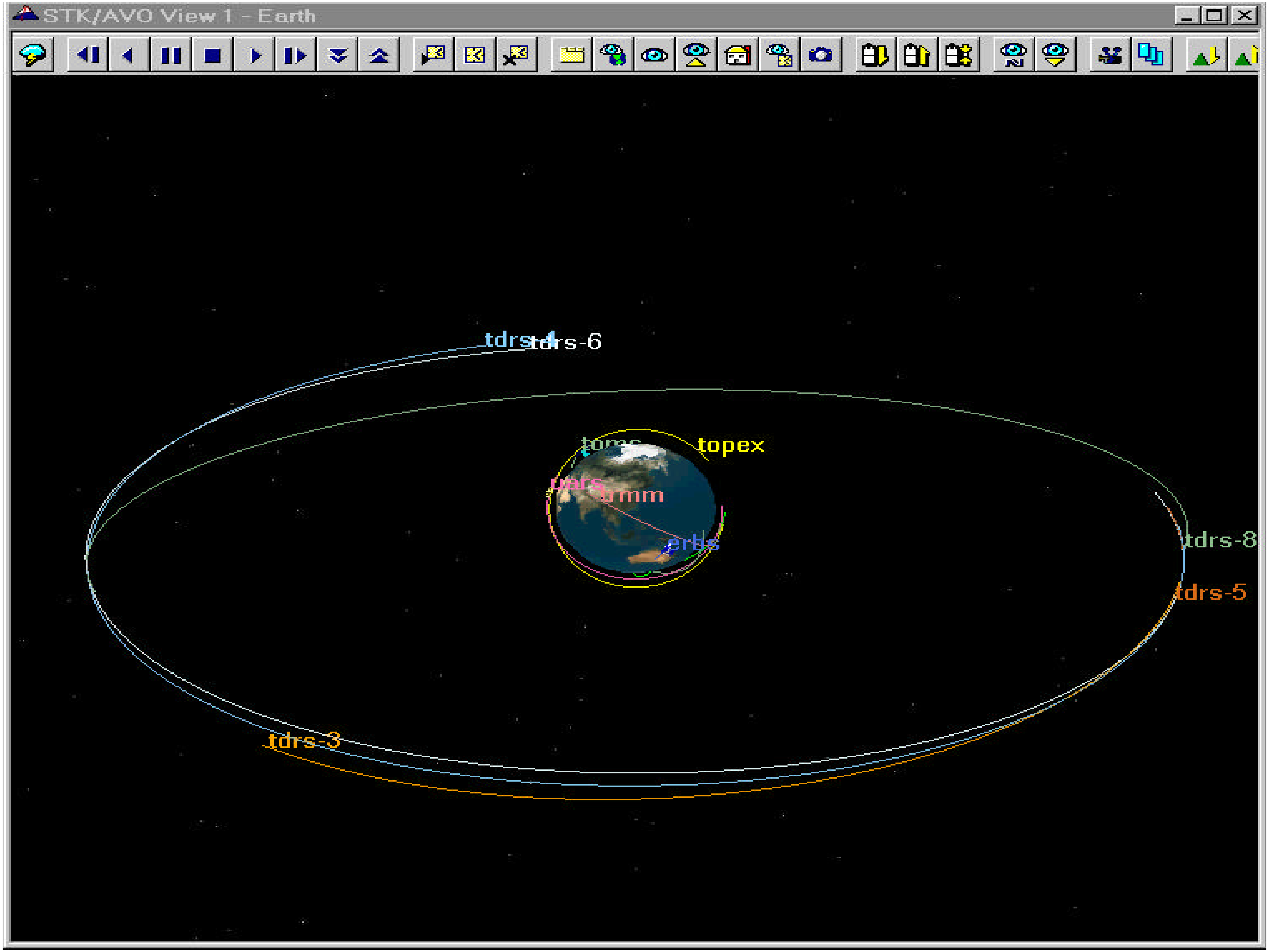
Orbits

- Polar Orbit
  - An orbit for which the angle of inclination is 90degress . A satellite in polar orbit will pass over both the north and south geographic poles once per orbit. This orbit is ideal for earth observation

- Geosynchronous Orbit
  - Any orbit about the Earth, which has a period equal to the period of rotation of the Earth about its axis. Weather and Communication Relay Satellites are typically found in Geosynchronous orbits

- Low Earth Orbit
  - A term used to describe the orbital altitude range (500 to 2000 km above the surface of the Earth) Generally, LEO satellites are part of constellations of satellites that achieve wide coverage of the Earth's surface with lower power requirements and shorter propagation delays than can be achieved with, geostationary satellites. GPS are in Low Earth Orbit




STK/AVO View 1 - Earth
tdrs-6
topex
uars
trmm
erbs
tdrs-8
tdrs-5
tdrs-3

Satellite Communications

Mission Operations

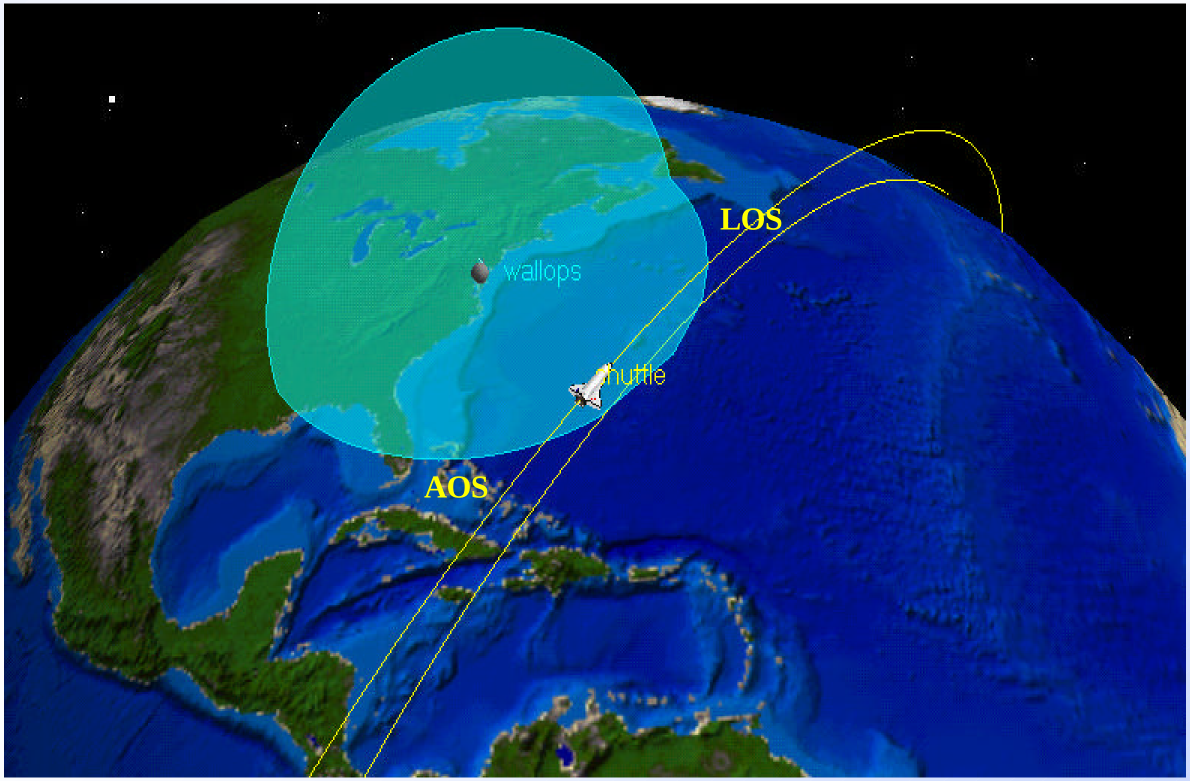
- Three primary elements are necessary for mission operations, and all are reliant on dependable communication systems
  - Satellite Tracking
    - » Where is my spacecraft
  - Satellite Telemetry
    - » Relay of acquired scientific or spacecraft “housekeeping” data back to earth
  - Satellite Command
    - » Upload commands or instructions to the spacecraft bus or payload

Satellite Communication Options

Satellite Communications

Ground Network Approach

- Ground Network Approach
  - Spacecraft flies over ground station at which time both uplink and downlink of data occurs
  - Typically view period lasts 8 minutes with an average of 2 to 3 opportunities for contact per day



Satellite Communications

The Low Earth Orbit Ground Network

SGS, Longyearbyen, Spitzbergen, Norway

WGS, Wallops Flight Facility, Wallops Island, Virginia

Satellite Communications
Deep Space Network

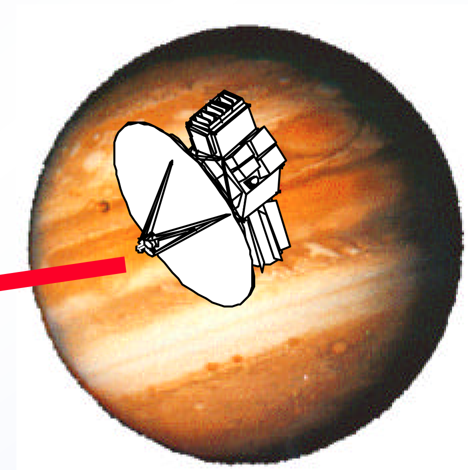
- The NASA Deep Space Network - or DSN - is an international network of antennas that supports interplanetary spacecraft missions and radio and radar astronomy observations for the exploration of the solar system and the universe.
- The DSN currently consists of three deep-space communications facilities placed approximately 120 degrees apart around the world: at Goldstone, in California's Mojave Desert; near Madrid, Spain; and near Canberra, Australia. This strategic placement permits constant observation of spacecraft as the Earth rotates, and helps to make the DSN the largest and most sensitive scientific telecommunications system in the world.
- The antennas and data delivery systems make it possible to: Acquire telemetry data from spacecraft. Transmit commands to spacecraft. Track spacecraft position and velocity. Perform very-long-baseline Interferometry observations.

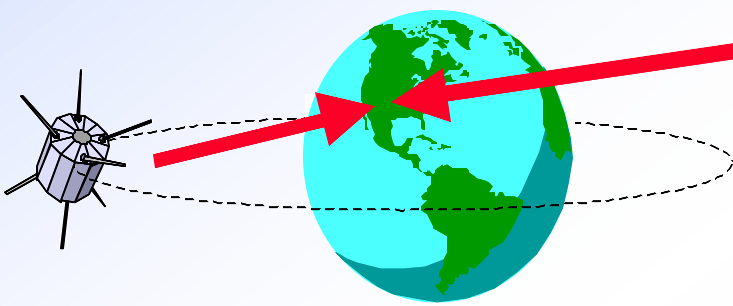
Goldstone, California

Satellite Communications

The Challenge of Deep Space Communications

- Communications performance decreases as the square of the distance
- **Jupiter is nearly 1 *billion* km away, while a GEO Earth communications satellite is only about 40 *thousand* km away**
  - **It's about 87 dB harder from deep space!**





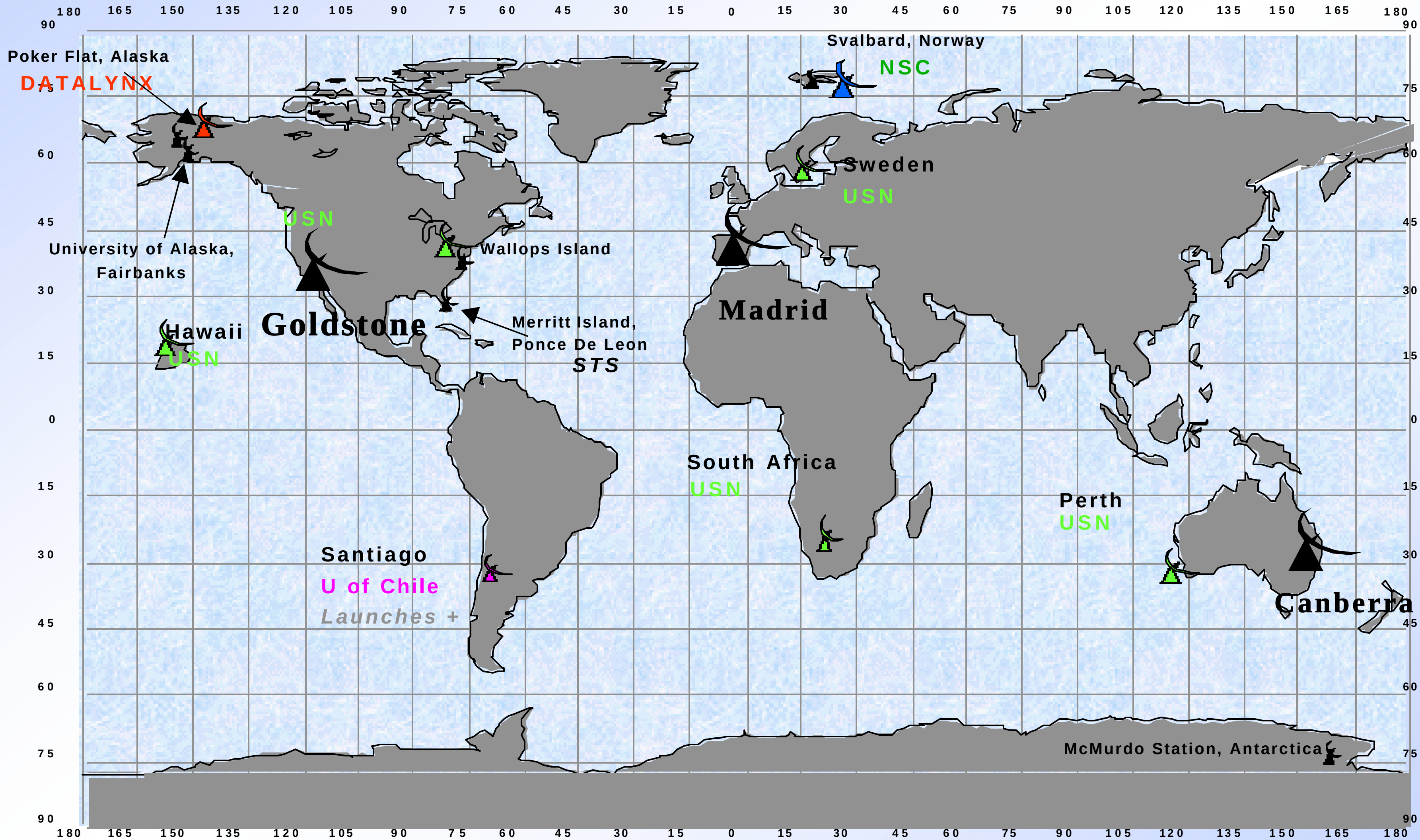
A loud person with good hearing, standing in front of NASA headquarters in Washington, DC, can talk with a friend a block away. Deep space communications would be like trying to talk with the same friend in Boston!

Key technologies that enable deep space communications:

- **Large aperture antennas**
- **Low noise amplifiers**
- **High frequency carriers**
- **Error correcting codes**
- **Data compression**
- **Precise frequency standards**

Satellite Communications

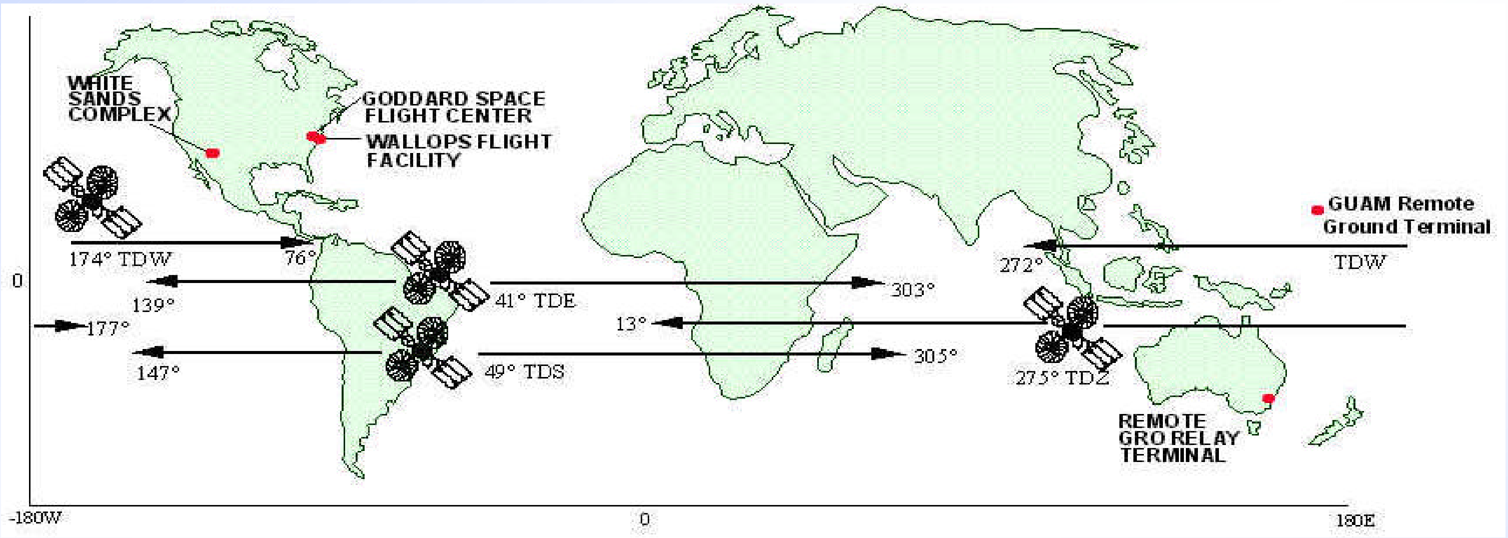
Deep Space Network & Near Earth Ground Networks



The Ground Networks provide limited contacts, ~15%, to Low Earth Orbit spacecraft and require planned commands and data dumps.

Satellite Communications

Space Based Relay Approach

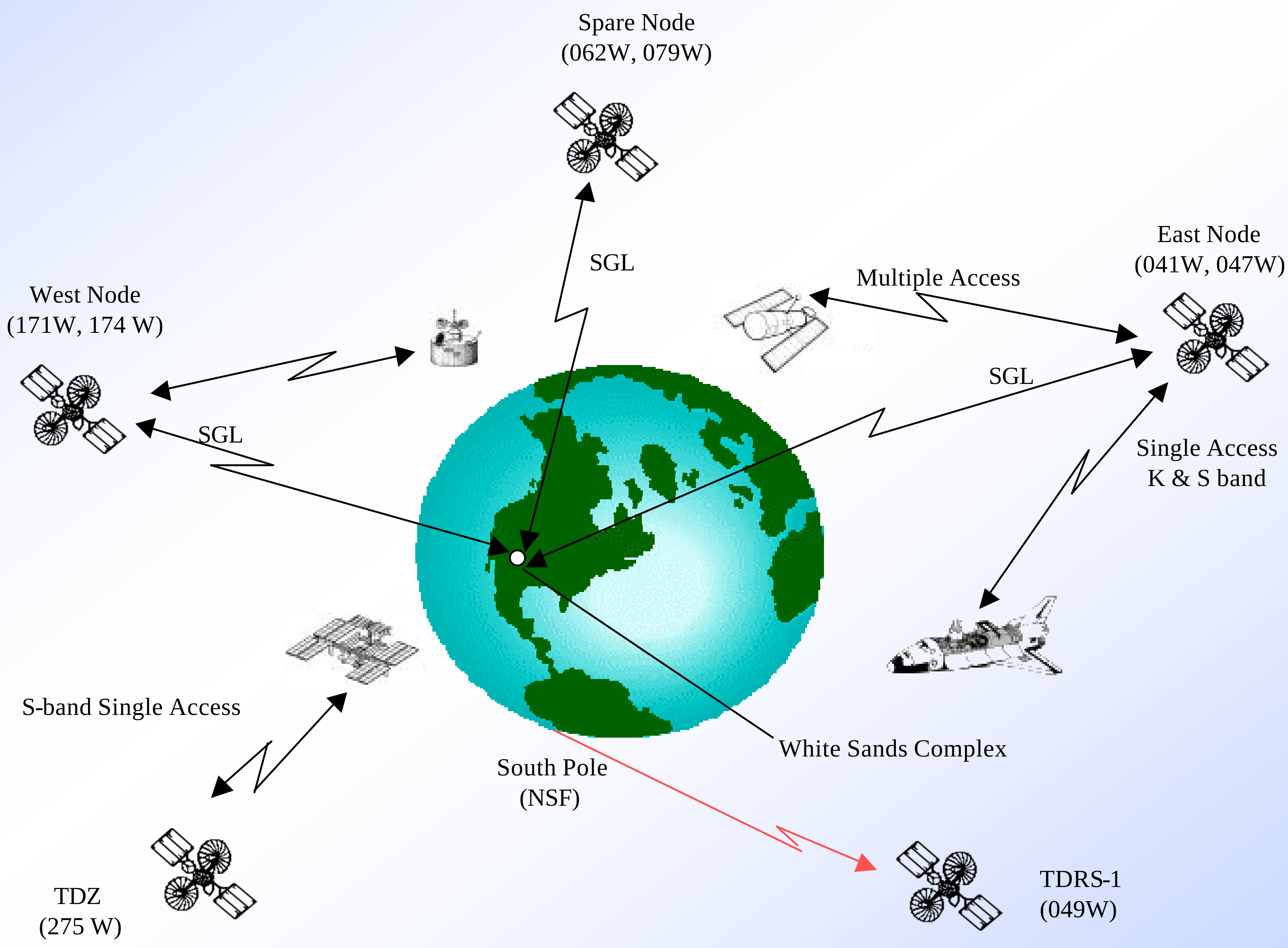


– Relay satellite network in geosynchronous orbit provides continuous visibility of target spacecraft

– Uplink and downlink can occur at anytime 24X7

Satellite Communications

Tracking and Data Relay Satellite System Baseline Configuration



Satellite Communications Evolution

Satellite Communications

Minitrack

The US entry into satellite communications came about in the late 1950s to participate in a multi-country project for the investigation of the Earth's atmospheric environment.

This involvement led to the development of the Minitrack which became the first US ground network to track orbiting space vehicles

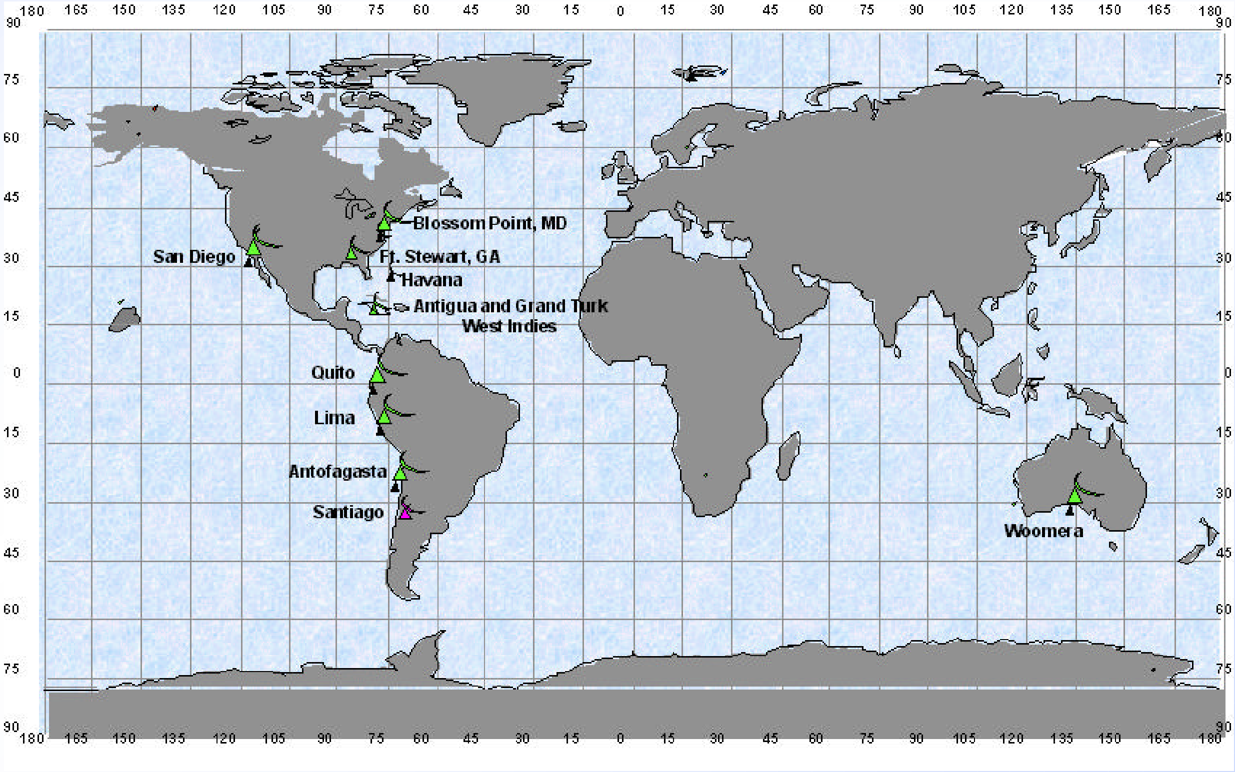
The Minitrack evolved into an 11 station network

Minitrack stations were equipped with:

Interferometry arrays for angle tracking

Fixed antenna for telemetry

A diamond shaped antenna for communications



Satellite Communications

Satellite Tracking and Data Acquisition Network (STADAN)

- Alterations in the Minitrack through the early to mid-1960s gave way to the new ground network called the STADAN
- STADAN stations provided
  - Effective tracking for satellites in higher orbits
  - Relocation out of VHF (136 MHz) to S-band (2300 MHz)
  - Introduction of the Goddard Range and Range Rate (GRARR) and Satellite Automatic Tracking Antenna (SATAN) systems.
  - Ground Network grows to more than 20 stations located worldwide
  - Centralization for Project Operations Control Centers (no need to locate satellite controllers and experimenters at the tracking stations)

Ascension Island

Satellite Communications

Manned Space Flight Network (MSFN)

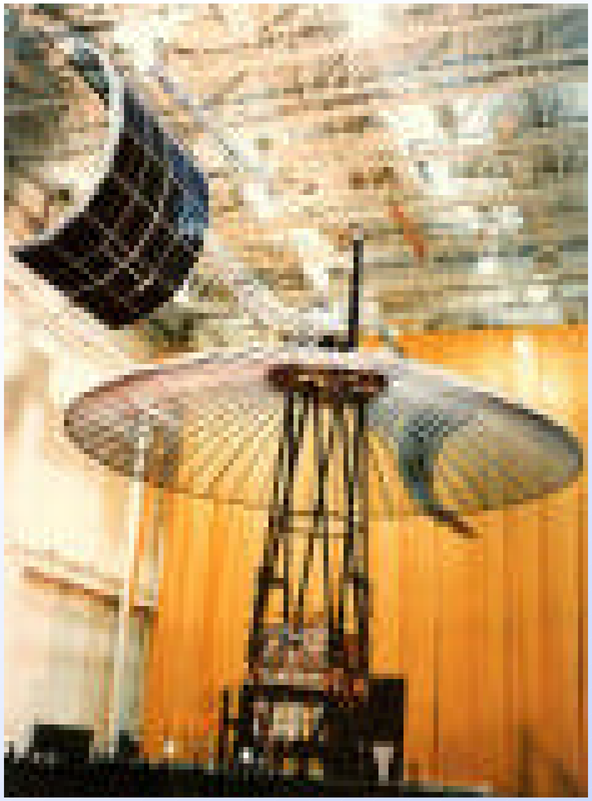
- Manned space flight brought a new set of communication requirements which were satisfied through the development of the MSFN. A more active and instantaneous communications path was required. Each project introduced additional requirements with an associated set of technical challenges to overcome
- Project Mercury phase introduced
  - Radar tracking rather than Interferometry
  - 2 way voice communication
  - 21 stations located worldwide
- Project Gemini phase introduced
  - Change from Analog to Pulse Code Modulation (Digital) telemetry and a digital UHF uplink command to the spacecraft
- Project Apollo phase introduced
  - The Unified S-Band System
    - » Allowed tracking, command, telemetry, voice and television to be combined on the same RF carrier
    - » Saved weight, space and power over need for discrete systems on spacecraft
    - » 56 kbps line rates (Same as a modem on your computer)

Satellite Communications

Space Flight Tracking and Data Network (STDN)

- The amalgamation of the MSFN and the STADAN into a single communications support network. Fully realized in 1975
  - Stations now capable of receiving up to 250 kbps telemetry data
  - Realization that space based relay satellites can increase communications coverage from about 15% of an orbit to 85% with 2 S/C constellation
  - Phase out of ground network begins in the late 1980s in favor of space based relay satellite system
    - » As of today only 3 STDN Ground Network Stations remain operational (MIL, WGS, AGS)

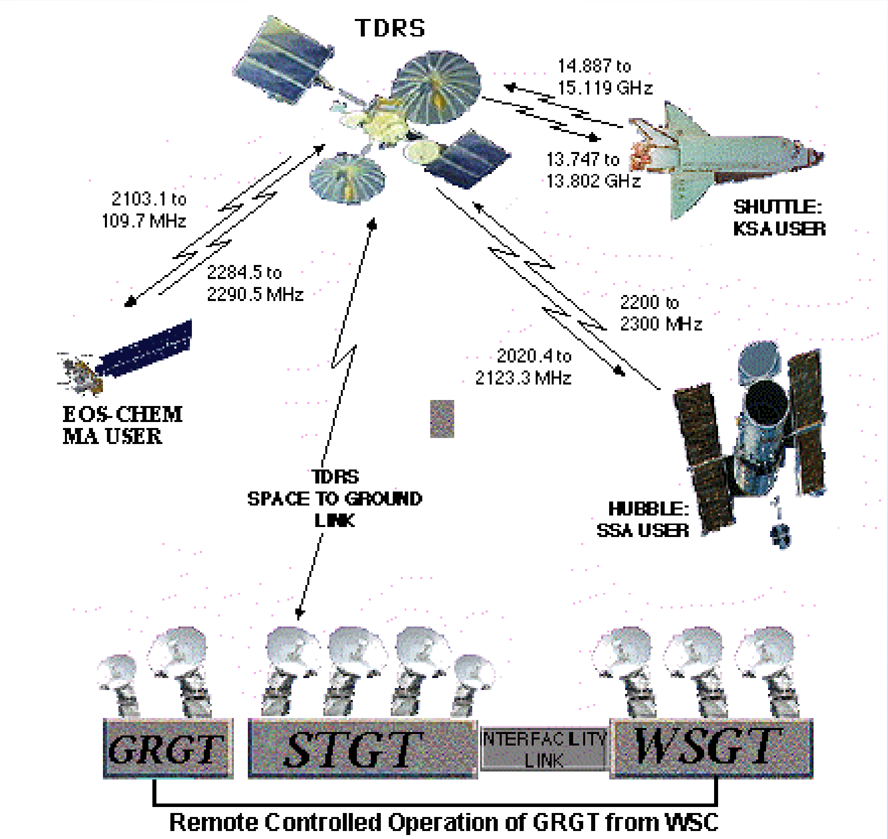
- Application Technology Satellites (geosynchronous communications satellite test project)
  - First support of space to space communication links, a forerunner to Tracking and Data Relay Satellite System (TDRSS)
  - Supported Skylab and the Apollo/Soyuz Test program for proof of concept



Satellite Communications

Tracking and Data Relay Satellite System (TDRSS)

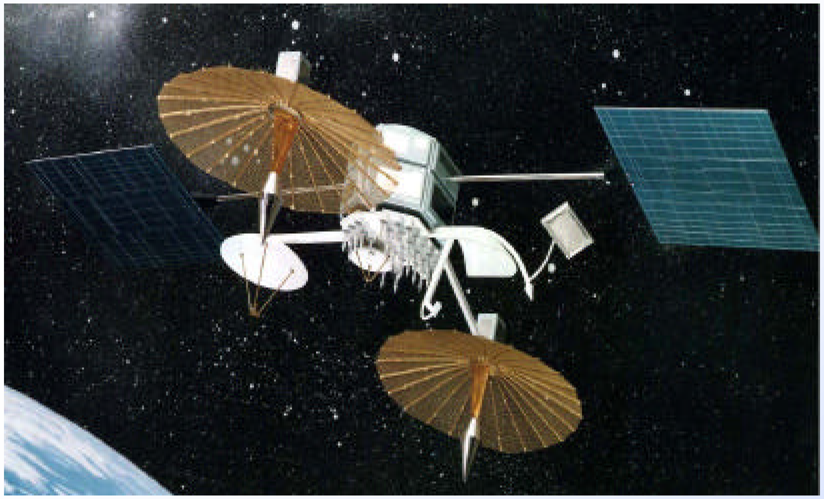
- TDRSS eliminates the need for worldwide network of ground stations
  - Eliminates reliance on treaties with foreign countries for the operation of ground stations on their soil
  - TDRS is essentially a ground station orbiting at geosynchronous altitude uplinking command data to satellites and downlinking telemetry to a single ground terminal located at Las Cruces New Mexico
  - TDRSS initially provides coverage over 80% of a satellites orbit (TDE, TDW in 1988)
    - » Coverage expanded to 100% with the addition of a Third Satellite and ground terminal in Guam
  - Supports S-band and K-band frequencies with data rates ranging form 100 bps to 300 Mbps (The equivalent of every page and picture in a complete set of encyclopedia every second)
  - TDRS H, I, J adds Ka-band capability with data rates to 650 MBPS



Satellite Communications

Tracking and Data Relay Satellites (TDRS)

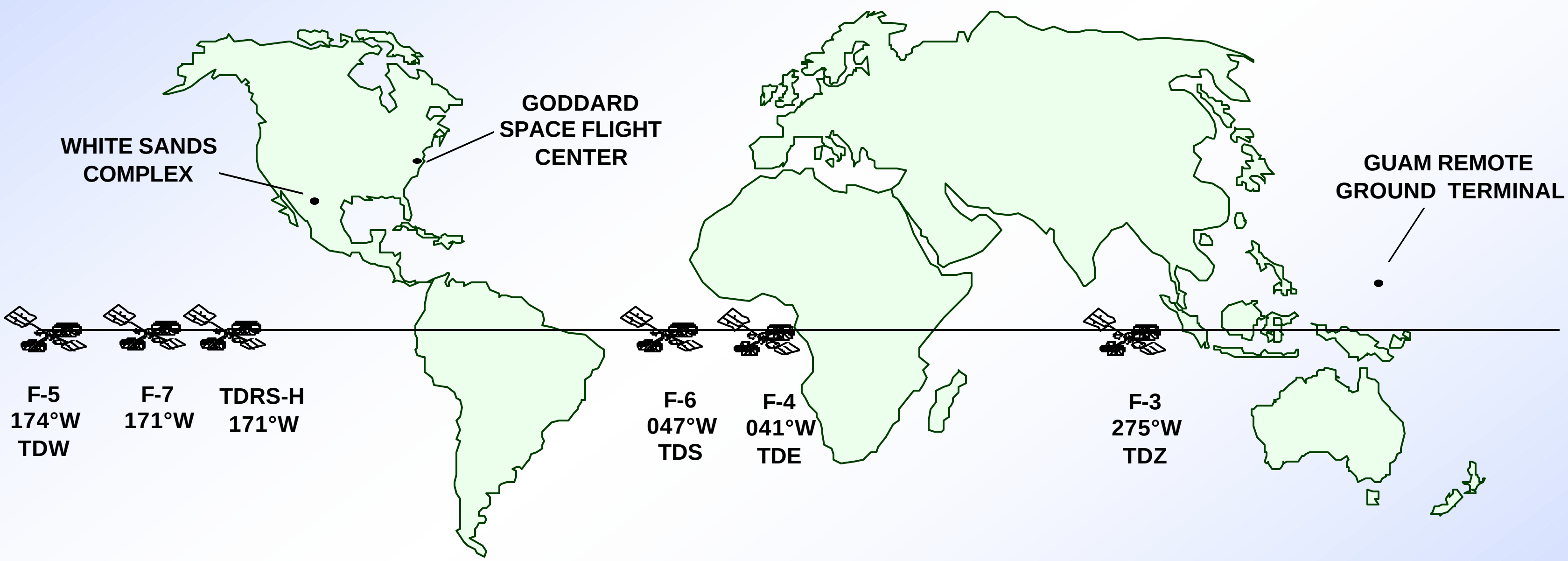
First Generation TDRS
F-1 through F-7



Second Generation TDRS
F-8 through F-10

Satellite Communications

TDRS Constellation



Satellite Communications

White Sands Complex

- TWO FUNCTIONALLY IDENTICAL, GEOGRAPHICALLY SEPARATED GROUND TERMINALS AT THE WHITE SANDS TEST FACILITY

THE WSC HAS FIVE SPACE TO GROUND LINK TERMINALS (SGLTs)

A SIXTH SGLT HAS BEEN INSTALLED AT THE REMOTE GROUND TERMINAL ON GUAM AS AN EXTENDED WSC SGLT

The Future

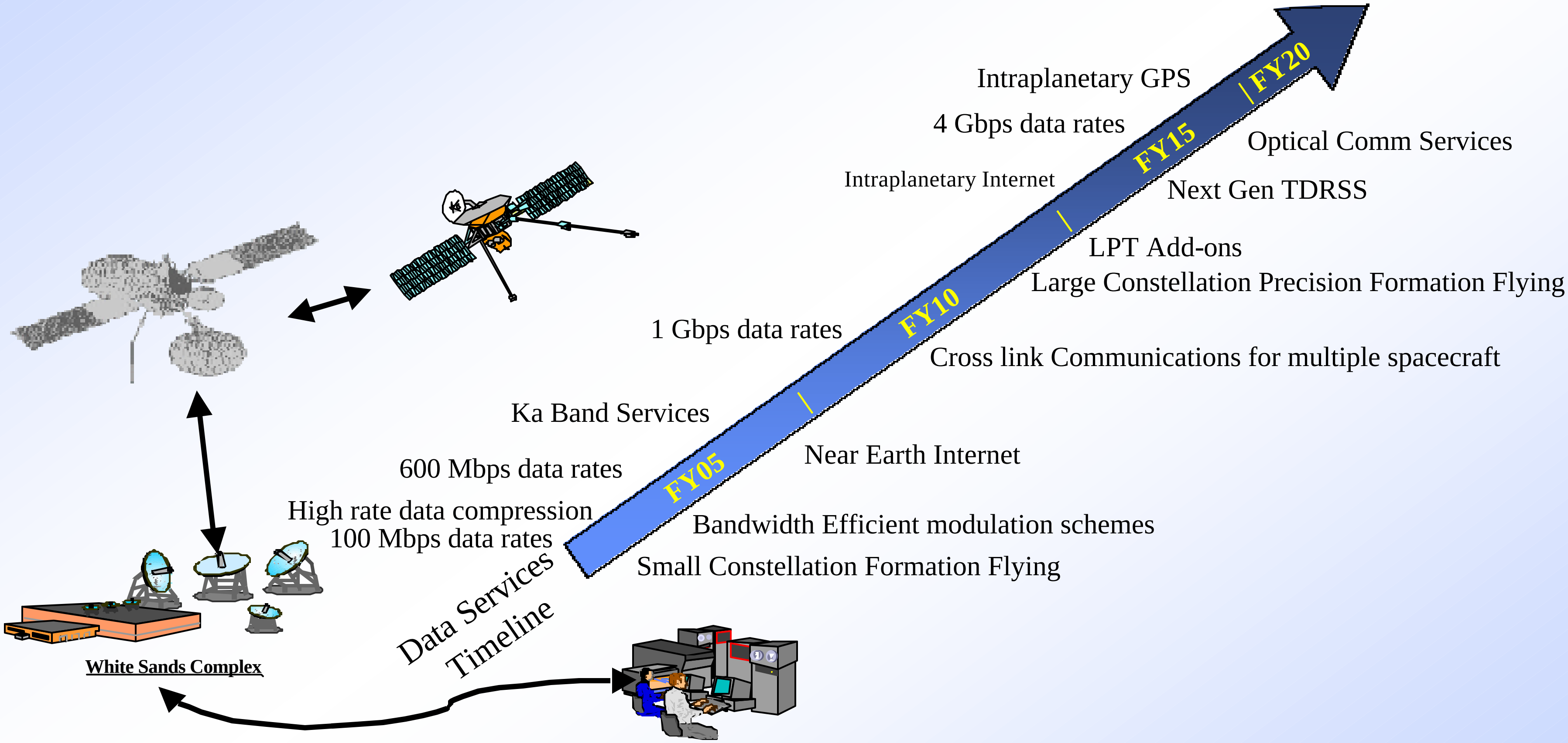
Satellite Communications

What's Next

- More efficient ground transport of data through standardization
- Improved data compression and storage in conjunction with higher data rates
- Increased spacecraft/ground terminal autonomy leading to true "lights out" spacecraft operations
- Optical Space to Space link
  - Enable high capacity data transfer (gigabits as compared to 200 to 300 megabits available today)
  - Highly secure with immunity to interference
- Lighter weight and lower cost communications equipments for both ground and space segments

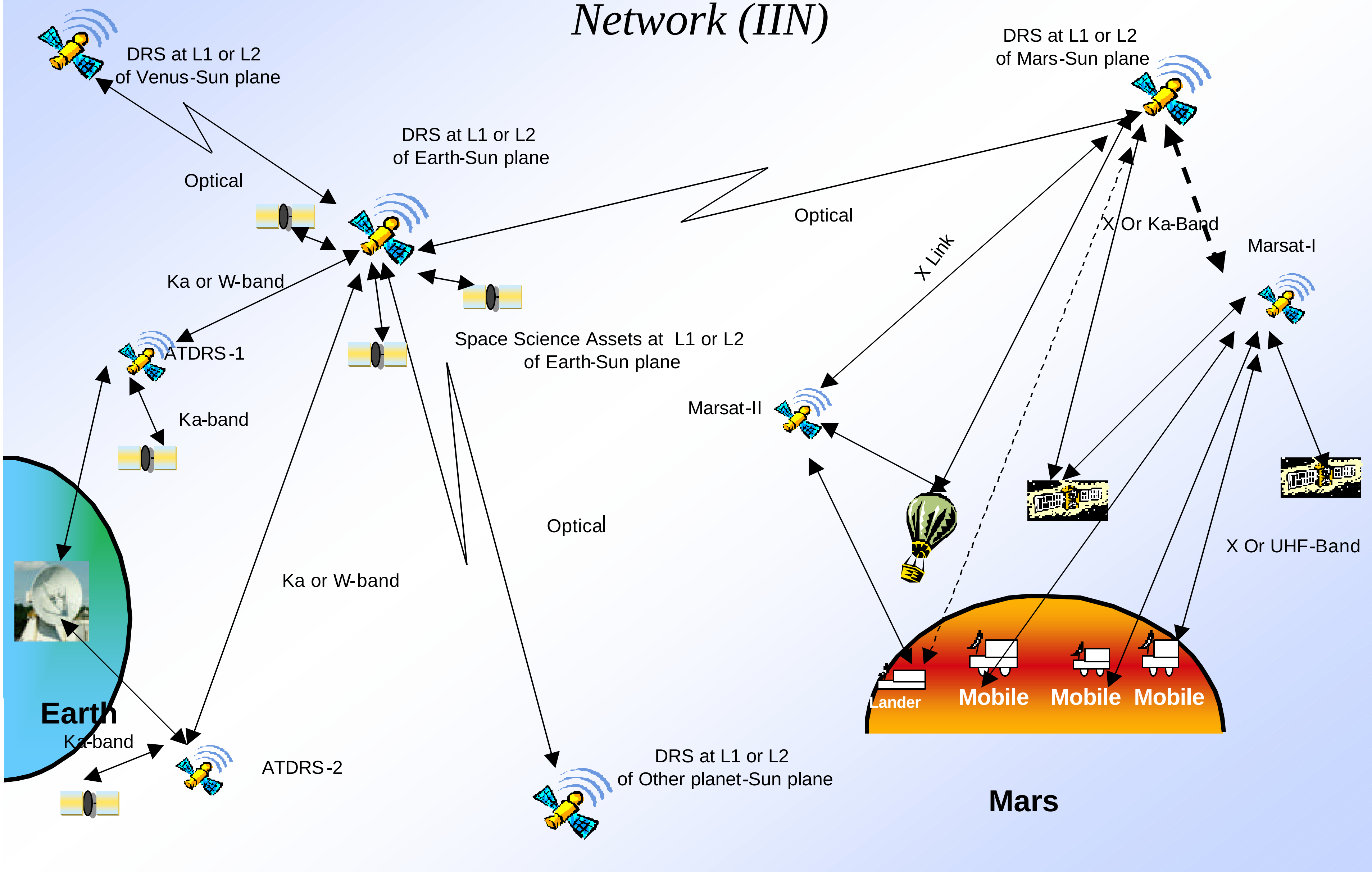
Satellite Communications

"The Out Years"



Satellite Communications

GSFC's Vision for Integrated Interplanetary Network (IIN)



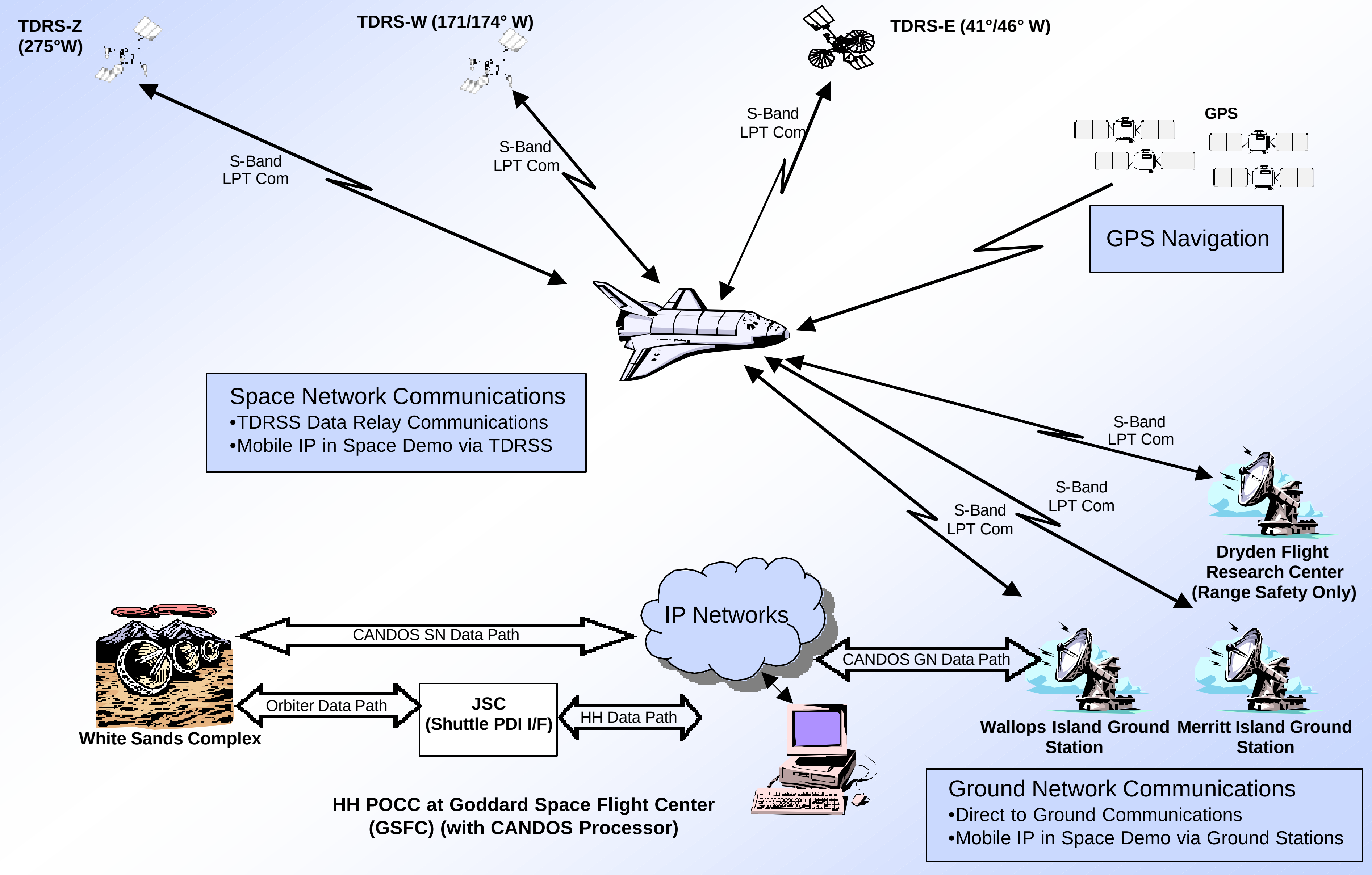
Applications and Products of Satellite Communications

Applications

- **GPS**
- **Home Satellite TV**
- **Telemedicine**
- **ISS High Rate Science**
- **Military Applications**
- **Internet**

Satellite Communications

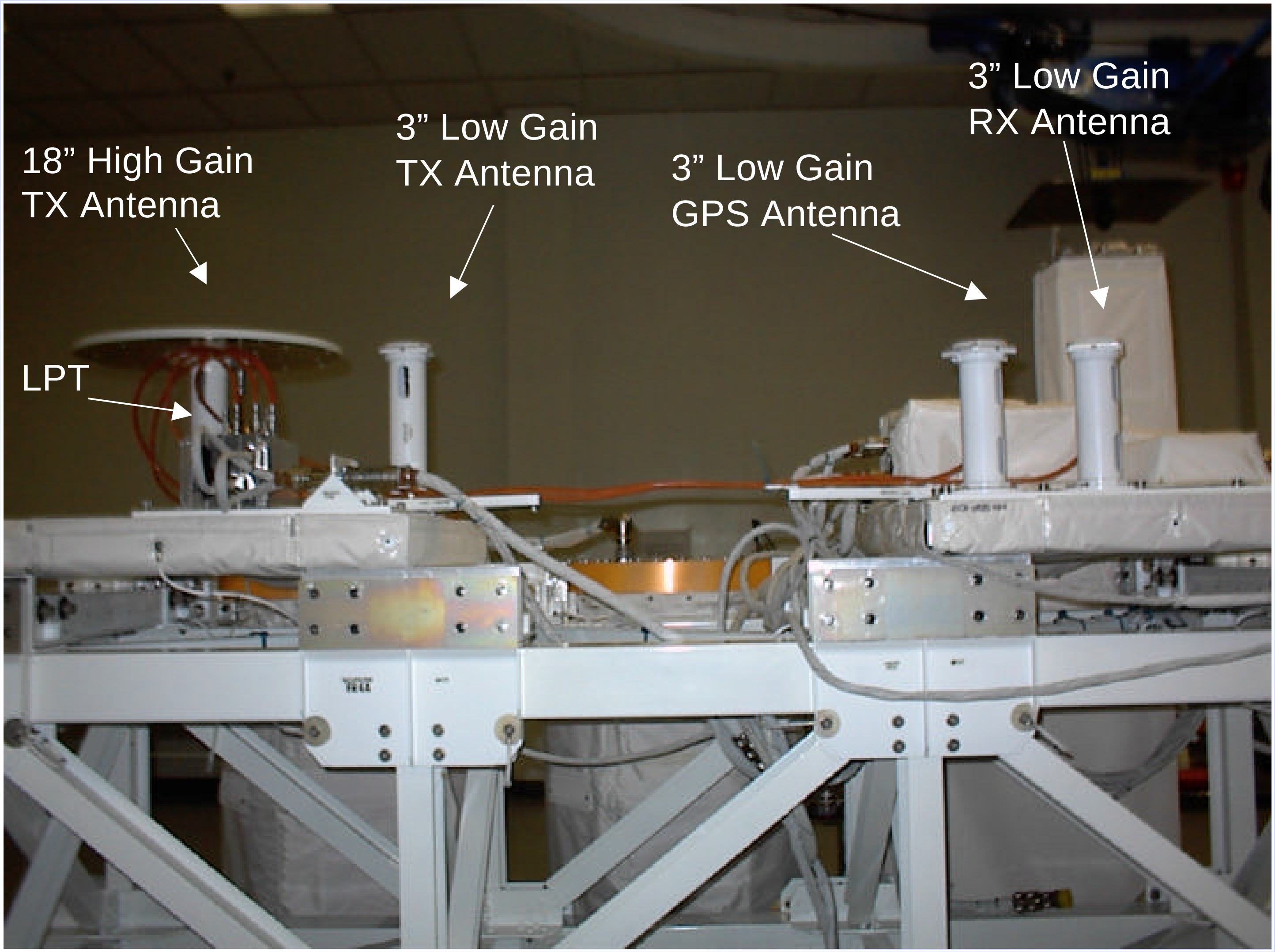
CANDOS Experiment Concept Diagram



Satellite Communications
On-Orbit Hardware

Satellite Communications

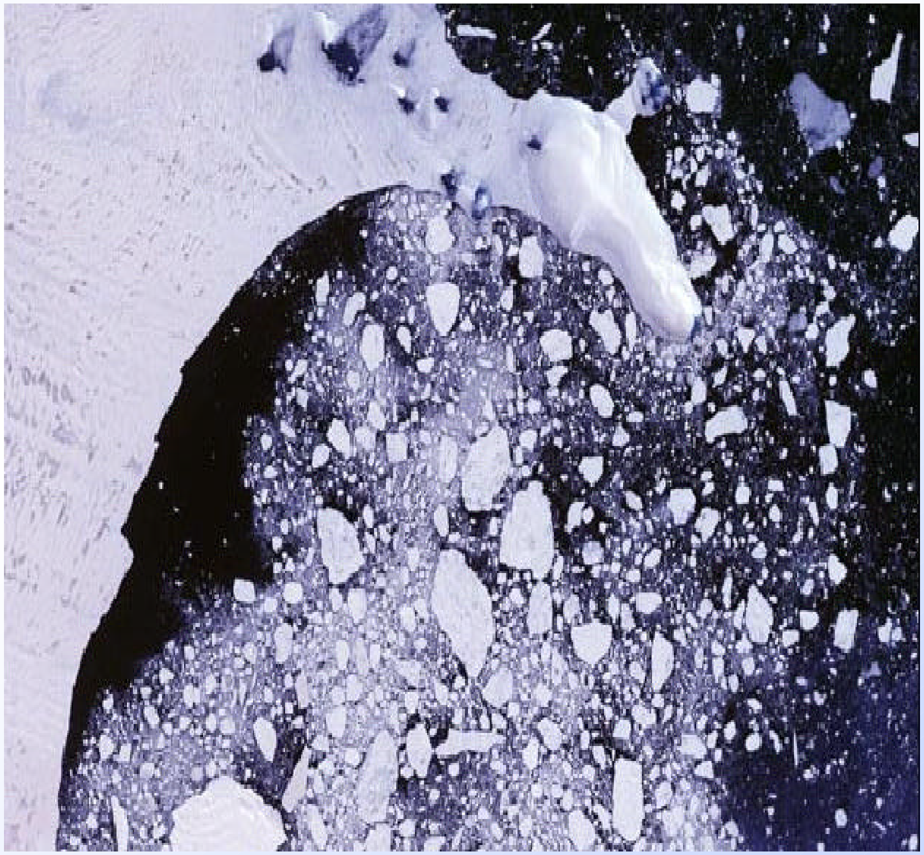
On-Orbit Hardware



Satellite Communications

Products

Using satellite images of tell-tale melt water on the ice surface and a sophisticated computer simulation of the motions and forces within an ice shelf, the scientists demonstrated that added pressure from surface water filling crevasses can crack the ice entirely through. The process can be expected to become more widespread if Antarctic summer temperatures increase. This true-color image from Landsat 7, acquired on February 21, 2000, shows pools of melt water on the surface of the Larsen Ice Shelf, and drifting icebergs that have split from the shelf.



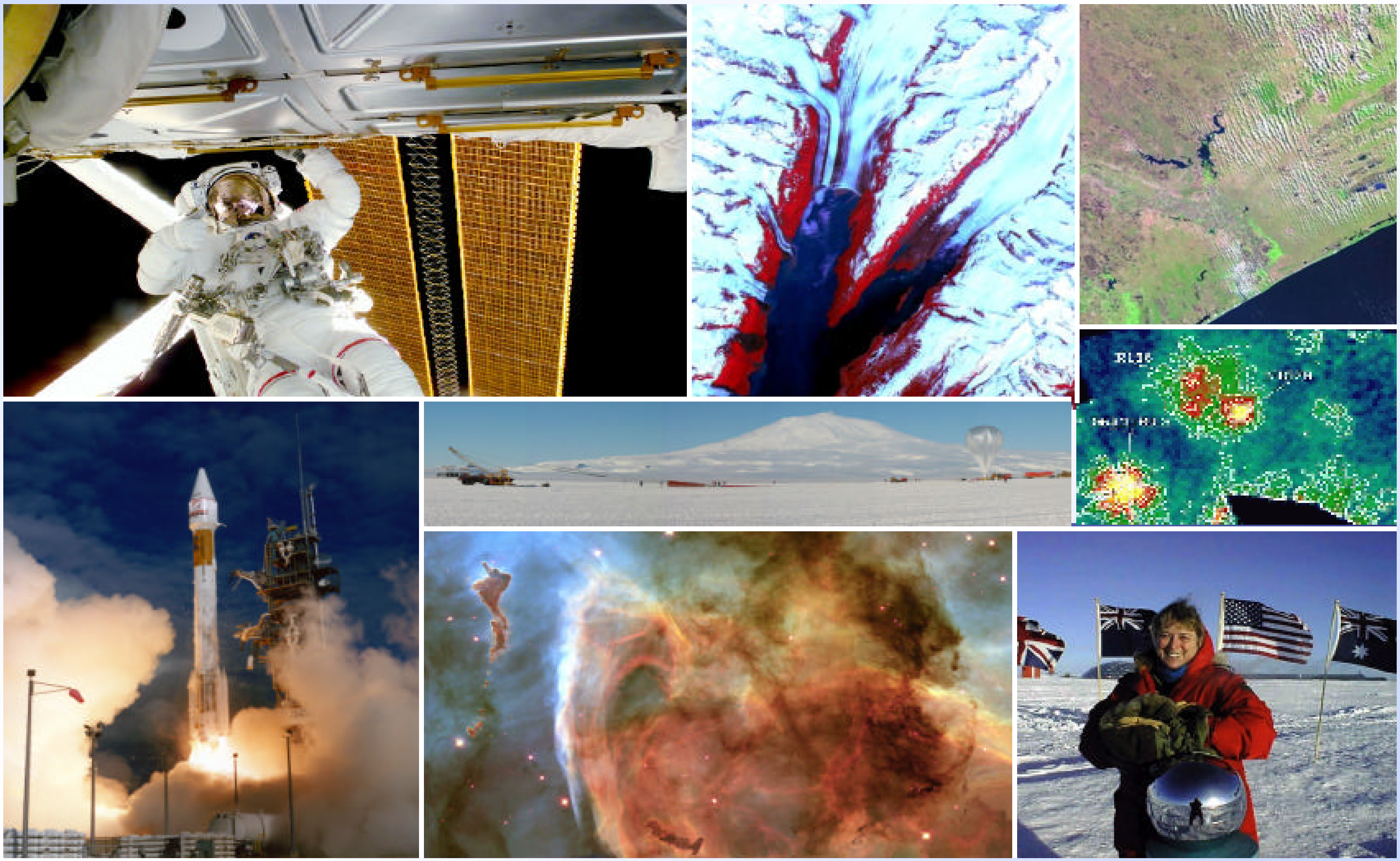
Satellite Communications

Products

- A planetary nebula represents the final stage in the evolution of a star similar to our Sun. The star at the center of IC 418 was a red giant a few thousand years ago, but then ejected its outer layers into space to form the nebula, which has now expanded to a diameter of about 0.1 light-year. The stellar remnant at the center is the hot core of the red giant, from which ultraviolet radiation floods out into the surrounding gas, causing it to fluoresce. Over the next several thousand years, the nebula will gradually disperse into space, and then the star will cool and fade away for billions of years as a white dwarf. Our own Sun is expected to undergo a similar fate, but fortunately this will not occur until some 5 billion years from now.

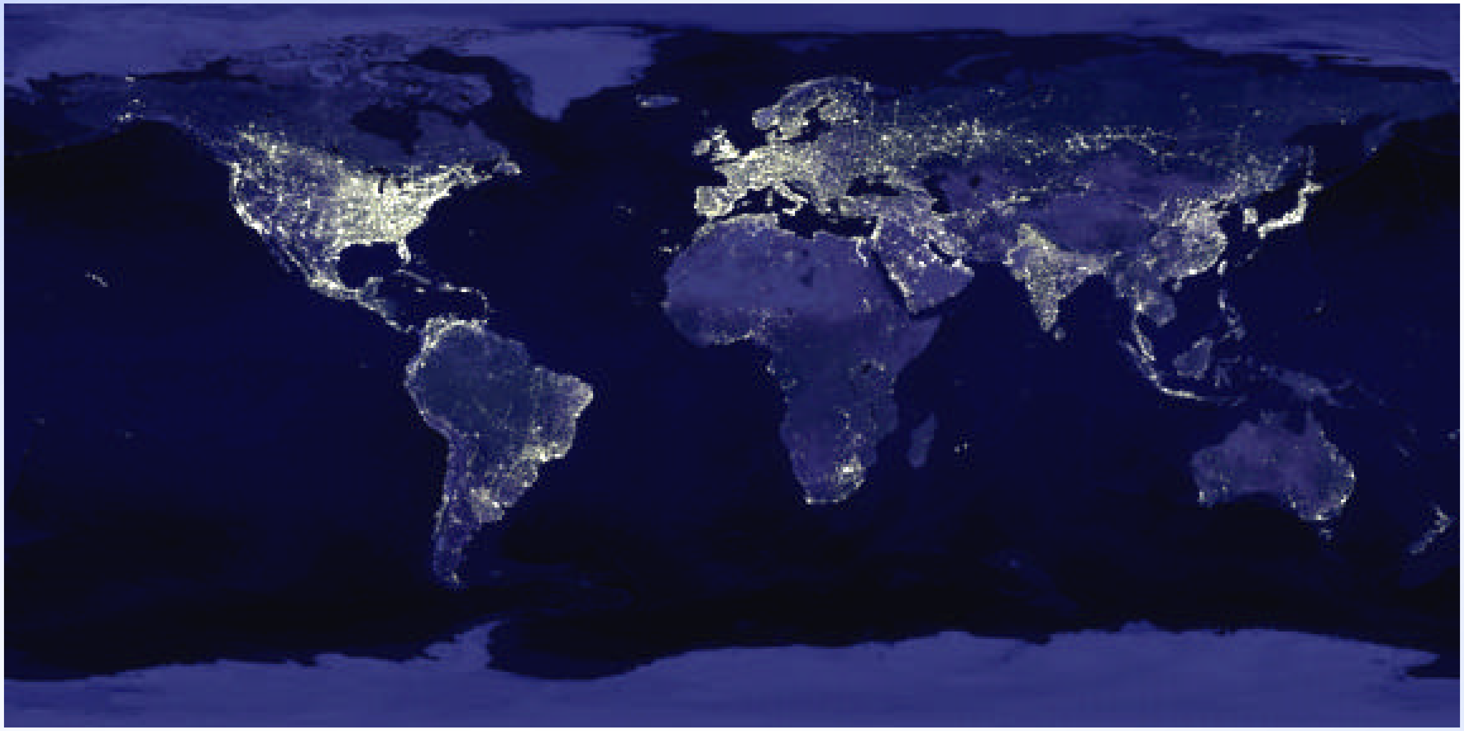
Satellite Communications

Products of Satellite Communications



Satellite Communications

Earth's City Lights



Credit: Image by Craig Mayhew and Robert Simmon, NASA GSFC, based on DMSP data courtesy Christopher Elvidge, NOAA National Geophysical Data Center
Satellite: DMSP

This image of Earth's city lights was created with data from the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS). The brightest areas of the Earth are the most urbanized, but not necessarily the most populated. (Compare western Europe with China and India.) Cities tend to grow along coastlines and transportation networks. Even without the underlying map, the outlines of many continents would still be visible. The United States interstate highway system appears as a lattice connecting the brighter dots of city centers. Even more than 100 years after the invention of the electric light, some regions remain thinly populated and unlit.

Resources

- **You can download or view this presentation at http://msp.gsfc.nasa.gov/tdrss/**
  - **Click on Space Network Presentations**